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## SECTION III.—FORECASTS AND WARNINGS.

## FORECASTS AND WARNINGS, DECEMBER, 1917.

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(Dated: Weather Bureau, Washington, Jan. 22, 1918.)

The exceptional features of the weather in December, 1917 was the pronounced and enduring cold that prevailed east of the Rocky Mountains and the abnormal warmth on the Pacific Coast. The statistical details of the cold weather will appear in Section VII of this REVIEW. The aspect of the weather that most impressed the forecaster was the southward and the eastward sweep of anticyclones from the Canadian Northwest: the large number of partly developed cyclones that drifted southeastward from the northern Plateau Region and the small number that eventually reached the Atlantic coast. Twelve so-called primary Lows and three secondary Lows have been charted. Of these but two, Nos. III and IVa (Chart III), were disturbances of marked intensity east of the Mississippi and both of these disturbances when last observed were moving northeastward toward Labrador rather than following the normal course eastward over the Atlantic.

With the exception of the Lows above named both HIGHS and LOWS suffered a decrease in intensity after passing east of the Mississippi. The concentration of the HIGHS over the Missouri Valley and the Canadian Northwest, while not exceptional, gave to the month its frigid character east of the Mississippi. Not a single HIGH moved inland from the Pacific.

## PRESSURE OVER THE PACIFIC AND ALASKA.

*Daily reports of pressure, temperature, wind, and weather.*—Daily reports of pressure, temperature, wind, and weather are received by cable and radio from two points in the Pacific and several points in Alaska. The geographical coordinates of the stations used in this discussion are as follows:

Station.	North latitude.	West longitude.	Elevation.
	° ' "	° ' "	Feet.
Midway.....	28 13	177 22	19
Honolulu.....	21 19	157 52	38
Dutch Harbor.....	53 55	166 30	50
Sitka.....	57 3	135 20	65
Eagle.....	64 46	141 12	834

The problem of the forecaster is how best to interpret the data received from these widely separated points, representing on the one hand subtropical areas of the mid-Pacific, and on the other sub-Arctic coastal and interior districts of Alaska. It is obvious that the individual daily pressures from these stations can have little direct bearing upon the preparation of the daily forecasts but may be of some value in their amplification or in an extension of the time beyond the present limits of 36 and 48 hours. Accidental pressure variations over continental areas have been investigated in more or less detail. In general, it is known that the amplitude of the variations increases with increase of latitude, but as between variations over sea and over land not much is known.

It is the general impression, however, that the stability of the pressure over continents is greater than that over oceans.<sup>1</sup> The accidental variations at the two Pacific stations are small, as might be expected from their low latitude. The fluctuations at Alaskan coast stations are approximately five or six times greater than at Honolulu; at California coast stations about three times greater.

It may be that the magnitude of the accidental pressure fluctuations along coastal regions of Alaska is in some way related to the very great contrast between the air temperatures over land and sea, respectively, which obtain in that part of the globe. The records themselves afford no indication of what the relation may be, but in seeking an explanation it may be recalled that the coastal stations are on the borderland between a marine climate on the one hand and a continental climate of unusual severity on the other, and that only a slight readjustment of the prevailing weather conditions may bring the coastal station more completely under the control of oceanic influences, or, on the contrary, the control may for the time become continental. In passing from one control to the other these large pressure variations may occur. An examination of the daily weather charts for Alaska shows that the transition from high pressure to low pressure in the interior takes place sometimes slowly and again rather quickly, but generally the action at both coast and interior stations synchronizes fairly well. The following values, taken from the December, 1917, records, is an example of how quickly an interior HIGH may break down when a LOW advances from the West.

*Pressure and temperature, interior and coastal Alaska, Dec. 12 to 16, 1917.*

Element.	December, 1917.					Place.
	12	13	14	15	16	
Pressure (inches):						
Interior.....	0.88	0.88	0.04	9.98	0.10	Eagle.
Coast.....	0.18	9.78	9.18	9.26	9.10	Sitka.
Difference.....	0.70	1.10	0.86	0.72	1.00	
Temperature (°F.):						
Interior.....	-52	-46	-28	-42	-54	Eagle.
Coast.....	20	28	26	28	30	Sitka.
Difference.....	72	74	54	70	84	

It is seen from the above that the fall in pressure began at Eagle, the interior station, a day later than on the coast; also that it was associated with a rise of 18 degrees in temperature. With the temperature 70 to 80 degrees lower at Eagle than at Sitka the sealevel pressure will naturally be about an inch higher. After making allowance for the difference in temperature it is seen that the level of the barometer reached at the two places was nearly the same.

*Accidental pressure variations.*—It is one of the established facts of meteorology that a fall in the barometer which sets in over any region generally progresses from west to east, sometimes at first with a southerly component and later with a northerly component, and that a rise in the barometer succeeds a fall and in general follows the same course as did the preceding fall. Since the advent of cyclones and anticyclones from the west

<sup>1</sup> Von Hann, *Lehrbuch der Meteorologie*, 3d ed., Leipzig, p. 201.

or northwest is the most important known weather control for the United States, it is not strange that much study should be devoted to the detection of the first sign of the development and movement of these weather controls. The rate of movement of cyclones across the United States, on the average of the year, is about 30 miles an hour, or 720 miles in 24 hours; over the North Atlantic it is about 20 miles an hour, or but 480 miles in 24 hours; over middle Europe it is still less, and over the Pacific little is known either of the development or movement of cyclonic storms beyond the statement in Weather Bureau Bulletin A that the average annual velocity over the North Pacific east of the Alaska Peninsula is about 18 miles per hour. In the Hawaiian Islands there occur in the cold season what are known as "kona" storms, the word "kona" meaning "leeward." Since the wind in these storms blows from the southwest or leeward side of the islands, the name "kona" has been applied to them as a descriptive term. Naturally a wind from the leeward side stands out in sharp contrast to the prevailing Northeast Trades. From what little information the writer has been able to gather concerning these storms, it would seem that they are neither more nor less than cyclonic depressions, or troughs of low pressure, with a longer axis, possibly 1,000 miles in length, advancing slowly from northwest to southeast and probably dissipating long before the North American coast is reached.

Cyclones occasionally pass inland over the coast of California, south of Santa Barbara, but it is not believed that they have pursued a lengthy course over the Pacific. If cyclonic depressions moved uniformly toward the east it would be a comparatively simple matter to announce their arrival on the Pacific coast. The experience of the last 40 years, however, shows beyond the shadow of a doubt that cyclonic and anticyclonic formations are not enduring; that the form of the bounding isobars is continually changing and that the level of the barometer at the center may increase or decrease with the lapse of time, and with each change in the level of the barometer there is a corresponding change in the intensity of the formations. Under the most favorable conditions some highly-developed cyclones have been traced halfway round the globe, but these are the exceptions.

The writer has given particular attention to the pressure distribution over that part of the Pacific in which Midway Island and Honolulu, Hawaii, are situated. Midway is about 4,000 miles and Honolulu about 2,500 miles from the coast of southern California. If, therefore, we assign to cyclonic depressions a speed of 480 miles in 24 hours it would require not less than five days to pass from Honolulu to San Francisco, provided the depression held together as a definite entity for the entire distance. The probability, however, is strongly against a continuous path of 2,500 miles without change in form or intensity. Unfortunately there is no way of identifying a cyclonic depression that may have been observed at Honolulu, for example, and one which a week or 10 days later may appear on the California coast. When ship reports become more numerous than they are now it may be possible to make a positive identification.

On December 10, 1917, the barometer at Midway sank to 29.56 inches by successive falls over a period of about five days. This low level was indicative of the presence of stormy weather in that part of the Pacific. In order graphically to present the daily fluctuations of the barometer at the two Pacific stations and at several pairs

of stations between Alaska and the California coast, a diagram has been prepared (not reproduced). This diagram shows that the fluctuations at the two points were in the same sense, that is, both rising or both falling, on 17 days; that they were in a different sense on 9 days, and that on 5 days there was no change at one or the other of the stations. The diagram does not show, however, any regular progression of the fluctuations from west to east. The marked fall at Midway, culminating on the 10th with a reading of 29.56 inches, did not appear in the readings at Honolulu three or four days later, although a very marked depression of the barometer on the southeastern coast of Alaska was observed on the 13th, three days later. This depression did not immediately pass inland, but seemed to develop northward along the coast on the 14th, 15th, and 16th—see the readings at Sitka in the small table on p. 607.

It might be assumed that because this depression appeared three days after the very considerable fall in the barometer at Midway, there was a direct relation between the two events. It is preferred to believe that the low pressure at Midway was a positive indication of a rather widespread barometric disturbance over that part of the ocean, with its center somewhere near the Aleutian group, and that an offshoot therefrom reached the Alaskan coast four days later.

#### HIGHS.

Eleven HIGHS have been plotted on Chart II, all of which originated in the Canadian Northwest and moved as shown on the chart. Two HIGHS, Nos. II and VIII, moved almost directly southward and dissipated over the Gulf States. High No. V moved southeastward in two branches, only one of which, the northern, endured until the Atlantic coast was reached. Three of the 11 HIGHS did not reach the Atlantic coast, and three others, Nos. VII, VIII, and VIII<sub>A</sub>, suffered a material reduction in speed of movement as they neared the Atlantic. The last HIGH of the month, No. VIII, was characterized by central pressures of 31 inches and over, and was distinguished from the others by the fact that the level of the barometer in the Low that preceded it did not fall below 30.05 inches until it had reached the Lake Superior region. The barometer over northern Saskatchewan and northern Manitoba, where it originated, stood at a high level with very low temperatures immediately preceding the beginning of movement of the HIGH. The movement of the HIGH became possible so soon as the pressure to the southeastward fell. This latter was an accomplished fact by the afternoon of the 26th, and on the morning of the 27th a shallow oval-shaped low, with central pressure 30.05 inches, was central over northern Lake Superior. The southeastward movement of the HIGH now became assured, and starting with an initial pressure of 30.80 inches it is not strange that a rise to 31 inches and over should occur during its movement over the Dakotas and the upper Mississippi Valley. The following successive pressures and temperatures at Battleford, Saskatchewan, show the rate at which the HIGH developed:

Battleford, Sask.		Pressure.	Temperature.
		Inches.	° F.
Dec. 26, 1917.....	p. m.	30.86	-22
Dec. 27, 1917.....	a. m.	31.00	-42
Dec. 27, 1917.....	p. m.	31.02	-36
Dec. 28, 1917.....	a. m.	31.10	-40
Dec. 28, 1917.....	p. m.	30.86	-28

This great HIGH moved eastward across the Great Lakes on the 28th and 29th and brought to eastern New York and New England the lowest winter temperatures that have been recorded since the beginning of Weather Bureau observations in 1870, the extreme minimum being reached at both New York and Boston on the morning of December 30, 1917. By this time the HIGH extended from the St. Lawrence Valley southwestward to Texas, its isobars forming a wedge-shaped configuration, with northeast to north winds in the eastern side of the wedge. Since the eastward advance of the HIGH was slow cold weather in Florida and the South Atlantic States was delayed until the morning of the 30th, and in central and southern portions of the Florida Peninsula until the morning of the 31st.

*Northers in Panama.*—One result of the eastward movement of this HIGH was a norther in the Canal Zone, which began December 30 and continued until January 2, 1918. Maximum velocities were attained as follows: Thirty-five miles per hour from the north on December 30, 31 miles per hour from the north on December 31, and 30 miles per hour from the north on January 1. The norther was attended by heavy rain, low temperature, and high pressure, the maximum reading 29.987 inches, being the second highest of record in the month of December.

I am indebted to Mr. R. Z. Fitzpatrick, Chief Hydrographer, Panama Canal, for the above information.

#### LOWS.

As before stated, but two Lows attained the intensity of severe winter storms and for that reason they will be given special attention.

Low No. III evidently originated over the North Pacific, but it was not until the morning of December 6 that the center was definitely located in the northern Rocky Mountains Region. At that time pressure southward to the Mexican border was relatively low. By the afternoon of the 6th the center of low pressure was in southeastern New Mexico (see Chart III, track No. III). This transformation was effected by a rise in pressure in the northern and central Rocky Mountain districts and a small fall in southern districts. By the morning of the 7th the form of this barometric configuration had become an oval whose longer axis extended from Abilene, Tex., to Roswell, N. Mex. The wind circulation about the center was cyclonic and the rapidity of the pressure fall to the eastward indicated that a severe cyclonic storm was about to develop. Precipitation had not yet begun, except over Kansas and in eastern Nebraska points somewhat far distant from the center of the LOW. The LOW increased in intensity during the 24 hours following 8 a. m. December 7, and moved rapidly to southeastern Kentucky by the morning of the 8th, thence continuing in a northeasterly direction to the mouth of the St. Lawrence and passing beyond the field of observation on the 10th.

The fall in pressure near the center of this storm was unusually rapid and the barometer sank to a level of 28.92 inches by the morning of the 9th. The fall in the barometer at Washington, D. C., from 11 a. m. to 3 p. m. of the 8th was 0.51 inch, a rate that is rarely exceeded even in tropical cyclones. The following account of this storm as it passed over Lake Erie is contributed by Mr. David Cuthbertson in charge of the Weather Bureau station at Buffalo, N. Y.:

The storm appeared as a well-developed Low over New Mexico on the 8 p. m. map of December 6. By 8 a. m. of the 8th it had moved

to eastern Kentucky and increased greatly in intensity. At 8 p. m. of the 8th it was centered over eastern Lake Erie and by 8 a. m. of the 9th it had moved to the middle St. Lawrence Valley. The high-pressure area in the Northwest on the afternoon of the 7th meanwhile had moved to Texas and a new HIGH had moved in from Alberta over the upper Mississippi and Missouri Valleys and the adjacent Canadian Provinces, thus furnishing the gradient necessary for the continuance of westerly gales.

On the morning of the 8th, while the storm center was over Kentucky, northeast storm warnings were issued from the central office at 9:30 a. m., for Lakes Huron, Erie, Ontario, and southern Michigan. Snow was forecast for Saturday night and Sunday with colder weather Sunday. Snow had already been forecast on the previous day for Saturday, the 8th. In the local forecast this was amplified to "Snow, probably heavy, this afternoon and to-night; Sunday, snow and decidedly colder. Strong northeast gales becoming west to northwest to-night or early Sunday morning. Hold all shipments in common cars. Marine interests should use caution."

Besides the maps and forecast cards and the usual distribution of the forecast and warning through the local press and by telegraph, telephone, and wireless, they were given to each of the daily papers in a news article in which emphasis was placed on the necessity of preparation by all interests concerned for a severe storm as the combination of gales, snow, and severe cold held dangerous possibilities. All railroads, shippers, and marine interests who could be reached by telephone were likewise warned to take extra precautions. The storm warning was changed to "northwest" at 2 p. m. Saturday and continued "northwest" at 2 p. m. Sunday, the 9th.

Snow began falling in scattered flakes at 7:20 a. m. of the 8th and in measurable quantities at 9 a. m. Except for two intervals of two and three hours, respectively, on Sunday, the 9th, snowfall was continuous until 7:05 a. m. of Monday, the 10th. The total duration of snowfall in measurable quantities was 41 hours 40 minutes and the total depth recorded was 25 inches. A comparison with the records of other years shows that this exceeds by 2.5 inches the maximum 48-hour amount previously recorded.

As the center of the storm passed near to Buffalo and northeast winds, being from the land, seldom reach high velocity at this station, not much increase in the wind velocity was noted while the wind remained in that quarter, though reported velocities from nearby stations show that the warning was amply justified. On the shift of the wind to westerly about 10 p. m. Saturday, the velocity increased at once to 48 miles per hour and the temperature began to fall. By 11:05 p. m. the velocity had reached 74 miles and at 4:34 a. m. of Sunday, the 9th, the maximum velocity for the storm, 78 miles per hour from the west, was reached. For the 3 hours ending at 5 a. m. Sunday the wind averaged 72 miles per hour, and for the 24 hours ending at 10 p. m. Sunday the average velocity was 56 miles per hour.

The temperature fell to 6° F. by 10 a. m. Sunday, and continued from 6° to 10° during the next 24 hours. The snow was dry and consequently caused no serious interference with communication by telegraph or telephone. With one exception marine interests heeded the warnings, even to the extent of two vessels which had left the harbor returning to their anchorage. Consequently there was no loss of shipping from this port. The experience of the *McCullough*, the only vessel which ventured out, is interesting and instructive. Under the command of Capt. J. S. Neal, the *McCullough* left Buffalo Harbor at 7:45 p. m. December 8, with a cargo of coal for up the Lakes, in the midst of heavy drifting snow and with falling barometer. The wind freshened and by the time she had proceeded 50 miles the vessel was in the midst of a howling gale and blinding snow storm. It was impossible to reach shelter so, about 20 miles off Long Point, the vessel was headed into the storm and the anchors dropped. There she remained until Tuesday morning when the trip was discontinued and she returned to Buffalo. Saturday night and Sunday the waves were so high that it was impossible to pass along the deck of the vessel. Tarpaulins were torn off the hatches and the upperworks of the vessel soon became heavily coated with ice which formed as fast as the water reached them. When she returned to dock at Buffalo the vessel was so heavily loaded with ice that her bows were down a foot deeper in the water than usual for the cargo she carried.

About 9 inches of snow had already fallen when the westerly gales began at 10 p. m. Saturday. With such a depth of loose snow on the ground and the high wind velocity attained trolley traffic was soon completely demoralized by the drifting snow. Interurban and steam roads fared but little better. Even when the storm ended and the snow plows had cleared the lines, movement of freight in the yards was practically impossible until the great accumulation of snow could be hauled out.

The greatest damage from the storm centers around the delay in transportation. Many of the Lake boats detained in port will not attempt another trip and this, with the great delay in rail transportation, in view of the critical conditions existing, amounts almost to a calamity. All losses, however, which were preventable were avoided through the timely warnings of the Weather Bureau.

The following excerpt from an editorial in the Buffalo Enquirer of December 11, 1917, is a fair sample of the favorable comment of the local press on the work of the Weather Bureau in forecasting the storm:

The severe storm which Buffalo has been experiencing since last Saturday was predicted in the forecasts sent from headquarters at Washington and supplemented by the local weather office. Early on Saturday morning warnings were issued to marine and commercial interests to use extreme caution in shipping and a general warning told of what was in store for Buffalo and vicinity.

Certain results of the forecast were that millions of dollars worth of perishable goods were saved from complete destruction and untold damage was avoided by marine interests. Shippers who are obliged to depend upon weather conditions for the safe consignment of goods by rail or water are no doubt congratulating themselves that they took the advice of the Weather Bureau and thus saved themselves much trouble and loss of money for if ever the efficiency of the Weather Bureau was established it was in this particular forecast.

In a similar vein the Buffalo Evening Times said on December 12th:

The marine and commercial interests were warned early Saturday morning by the Weather Bureau that heavy snow was to be expected in Buffalo and vicinity Saturday and Sunday, accompanied by strong gales to be followed Sunday by decidedly colder weather. Storm warnings were displayed and the marine interests were told to use extreme caution, and shippers of perishable goods were advised to hold all shipments.

The people of Buffalo need not be told that the above forecast and advice was fully verified, for they experienced one of the severest storms that have passed over this vicinity in many years, and the Weather Bureau has again proven, as it has many times before, that it can be depended upon to warn the public when storms of a destructive character are about to occur.

Low No. IV<sub>A</sub> (Chart III), the second case of sudden development in intensity, had a history much similar to Low No. III, especially in the early part of its course. This Low was first observed over British Columbia on the morning map of the 11th with a central pressure of 29.50 inches. It developed rapidly to the southeastward during the next 36 hours, but the rapid southward movement of HIGH No. IV (Chart II), appears to have divided the Low into two portions—a northern and a southern. The southern portion filled up but the northern portion—see track No. IV<sub>A</sub>—moved eastward at first as a shallow cyclonic depression but during the afternoon of the 13th developed into a vigorous cyclonic storm and passed northeastward over New England on the 14th.

In this, as in the previous case, there was nothing in the surface conditions to indicate an increase in the intensity of the cyclone, except the fact that pressure fell more rapidly than usual, and this fact seems to be the only indication available to the forecaster as to an increase or diminution in the intensity of cyclonic storms. In this connection it may be worth while to refer to some of the surface phenomena of cyclonic depressions passing southeastward from the Pacific coast to the Gulf of Mexico. Our first comment is that cyclonic wind circulation in these depressions is imperfectly organized. This may be due to two considerations: first, owing to the uncertainties in barometric reductions to sealevel known to exist for the Rocky Mountains and Plateau regions the center of the Low may not have been placed in its proper geographic position; and second, the observing stations are widely scattered; some are separated from each other by high mountains, others are situated in valleys or depressions which largely control the wind direction. It is, therefore, to be expected that the mapped circulation about a low in that region will be more or less imperfect. On the other hand, when the wind shifts, or backs, to north the effect of irregularities in topography disappear—there is almost absolute uniformity in the direction of the winds, all being from a

northerly quarter, and the force is much greater than from any other quarter.

Our second comment is that the movement of a depression over the Rocky Mountains region seems to be almost wholly dependent on the "force" or "driving power" of the HIGH to the northward; and the strength of the HIGH seems to be proportional to the depth of the depression in its front. In other words, the greater the contrast between temperature and pressure (I say temperature and pressure advisedly) the greater is the speed with which the depression is forced toward the southeast. This point has already been touched on in the account of the two LOWs above mentioned, and it has also been pointed out that of the surface winds northerly winds are uniformly the stronger. From these facts it seems reasonable to infer that the superior force of the northerly winds, largely if not wholly a gravitational force, literally swept that portion of the depression immediately in contact with the surface, far to the southeastward; that there remains a disturbance in the upper levels which may or may not be continuous with the remnant on the surface appears quite likely, and this view is strengthened by the sequence of events attending Low No. IV<sub>A</sub> (Chart III). In this case the level of the barometer over British Columbia just after the low passed inland was 29.50 inches: when it reached Colorado the level at the center had risen to 29.74 inches. Then began the aweeping movement in the rear, due to the superior force or driving power of high pressure and low temperature in Montana and to the northward. As a result in 12 hours the center of low pressure apparently had been separated into two parts: one of which was over Texas with a central pressure of 29.86 inches, an increase in central pressure of 0.36 inch; the second part being over eastern Missouri with a central pressure of 30.14 inches, an increase of 0.64 inch. In 24 hours the southern depression had disappeared and the northern depression was central over Indiana with its lowest pressure at 30 inches, and singularly the precipitation in connection with it was confined to the northern and western quadrants, a condition not usually occurring in depressions east of the Mississippi. The surface winds were light, but the circulation was truly cyclonic. Temperature was low and the ground snow covered, yet the barometer fell rapidly during the 13th, the wind increased in force, and a severe winter storm developed.

It is difficult to explain this marked increase on the basis of surface conditions, and indeed it is not easy to explain it from upper-air conditions without indulging in more or less speculation. It does seem, however, that the circumstances recited above lead to the inference that the seat of energy of the Low does not rest on the surface, but rather that there is a column of warmer air whose upper limit may extend to 5 kilometers, and possibly higher, in which cyclonic depressions are carried along; that this warmer upper current is underlain on its western margin by a cold, dry current from the north or northwest which does not extend upward much above 3 kilometers. While these altitudes are approximate they are based, in part, on the evidence afforded by kites and mountain observations as to the relative shallowness of the northerly winds that flow over the Plains States directly east of the Rocky Mountains. The existence and height of a southwest current is inferred from the movement of upper clouds at stations in the Southwest, particularly New Mexico, Texas, Arkansas, and Oklahoma, supplemented by kite observations at Mount Weather, Va., and Drexel, Nebr. Much critical examination of the movement of cyclones and anticyclones is yet required before definitive statements can be made.

## WARNINGS.

Storm warnings were issued as follows: On the Great Lakes, or some portion of them, on December 2, 8, 9, and 17; on the Atlantic coast, or some portion of it, December 1, 6, 8, and 13; on the Middle Gulf coast on December 7 and 11. Cold-wave warnings were issued for some part of the Washington Forecast District on December 7, 8, 9, 13, 14, 22, 23, 24, 25, 27, 28, and 29. Warnings of frost and freezing temperature in the truck regions of the South were issued, in connection with the daily forecasts, on numerous dates. Reports of activities at other forecast centers follow.

## WARNINGS FROM OTHER DISTRICTS.

*Chicago, Ill., forecast district.*—The weather during December, 1917, over most of the Chicago forecast district was abnormally cold with frequent precipitation, practically all of which was in the form of snow. Periods of temperature above normal were short and infrequent, and cold weather persisted throughout practically all sections.

The first cold-wave warnings of the month were issued on the morning of December 6 for North Dakota and eastern Montana in connection with an area of high pressure over Saskatchewan. By the morning of the 7th this area had assumed the proportions of a well-marked cold wave, preceded as it was by a rapidly deepening depression central over western Texas. Warnings were therefore extended to all the remaining portions of the district, except the extreme eastern sections, where at that time, the temperatures were already low. During the day, the disturbance over Texas moved northeastward increasing in intensity and causing unusually heavy falls of snow in the southern portions of Missouri and Illinois. It was followed by extreme cold for so early in the season, record low temperatures for December being reported at some points on the morning of the 9th. All warnings issued for this cold wave were fully verified.

Another cold high area appeared over Alberta on the morning of the 8th, and moved rapidly southeastward, causing a continuation of the cold weather over practically the entire district. As the temperatures were then already abnormally low over most sections, no warnings were issued during the passage of this high over the district, except on the evening of the 8th to Cheyenne, Wyo., Rapid City, S. Dak., western Nebraska and western Kansas, and on the morning of the 9th to southeastern Kansas. These warnings were partially verified.

The weather map on the morning of the 11th indicated the development of a low pressure area over eastern North Dakota extending southwestward and then northwestward to a deep depression in British Columbia, with severe cold and high pressure in the Canadian Northwest. By evening the pressure over the latter section had increased considerably and, anticipating its movement eastward and southward in the rear of the crescent-shaped trough which had deepened and moved southward during the day, warnings were issued to Wyoming and northwestern Montana. The temperatures at that time were much below 0°F. over North Dakota and the balance of Montana. The 8 a. m. map of the 12th indicated and warnings were sent to all points as far south as Kansas and northwest Missouri and as far east as southeast Wisconsin; and on the basis of the 1 p. m. special observations, they were extended to include the remainder of the eastern portion of the district. All warnings in connection with this cold wave were verified

with the exception that in eastern and extreme southern Illinois a verifying temperature fall was not reached, although readings close to 0° were reported.

The last cold wave of the month first appeared at Edmonton on the evening of December 22, and warnings were then issued for North Dakota and eastern Montana. During the 23d a crescent-shaped depression formed in front of this high-pressure area with a trough reaching from western Lake Superior southwestward and westward across the middle Rockies to the Plateau Region, thus producing ideal conditions for an extensive cold wave. Warnings for severe cold with strong winds were issued successively—from the 8 a. m. map, 1 p. m. special observations, and the 8 p. m. map—for all regions likely to be affected within the next 24 to 36 hours, so that by the morning of the 24th, the entire district east of the Rocky Mountains had been covered with the exception of eastern Illinois, where the cold was not expected to be severe owing to the high temperature prevalent during the 23d. Although the temperature in Kansas and Missouri did not reach as low a point as expected, the cold was severe over the northern and central portions of the district and the warnings fully justified.

On the morning of the 25th, the pressure had increased to a reading of 30.82 inches at Moorhead, Minn., with indications of a reinforcement over Saskatchewan and Manitoba, but owing to a development of a low-pressure area over the middle Plains States during the 26th, the southward movement of the reinforced cold was delayed until the night of the 26th. The morning map of the 27th showed intense cold in the Canadian Northwest with the remarkably high barometric pressure of 31 inches at Battleford. These extreme conditions advanced slowly eastward and southward during the 27th and 28th and were preceded by warnings for severe cold well in advance, practically all of which were verified. At many points in the Middle West, the lowest December temperatures of record were reported, and on the 28th barometric readings as high as 31.18 inches were recorded over the Dakotas and adjoining sections.

Temperatures considerably below normal prevailed over the district east of the Rocky Mountains until the end of the month, although a marked moderation had set in over western sections by the evening of the 31st.—*Ernest H. Haines, Meteorologist.*

*New Orleans, La., forecast district.*—Frost or freezing weather warnings were issued for the southern portion of this district on December 6, 10, 13, 14, 25, 28, 29, 30, and 31. The frosts or freezing temperatures occurred as forecast, and neither condition occurred without warnings being issued.

Cold waves were of frequent occurrence and warnings were issued as follows:

December 7, 9:45 a. m., cold wave—Oklahoma, western Texas, and the northern portion of eastern Texas; 2:30 p. m., for southern Texas; and 9:30 p. m., for southern Texas and eastern and southern Louisiana. The warnings were fully justified.

December 11, 1:30 p. m., cold wave southeastern Louisiana; was justified.

December 12, 2 p. m., cold wave northwest Arkansas, Oklahoma, western Texas, and the northwestern portion of eastern Texas; 9:30 p. m., Oklahoma and Texas except on the immediate coast, and at 9:55 a. m. of the 13th for southeastern Louisiana. Intense cold prevailed nearly to the coast and the warnings were justified.

December 23, 9:45 p. m., cold wave, Oklahoma, northern portion of western Texas, northwestern portion of eastern Texas, and northwestern portion of Arkansas; on



the 24th, 9:50 a. m. and 2 p. m., for Arkansas, Oklahoma, Texas except the immediate coast, and northwestern Louisiana; at 9:30 p. m., for Arkansas, Louisiana except southeastern portion, and for the eastern and southern portions of eastern Texas; on the 25th, 10:45 a. m., for the Texan coast and Louisiana except northwestern portion. A decided fall in temperature occurred but the high-pressure area did not follow the anticipated course toward the southeast and verifying temperatures were recorded at only a few stations.

Intense weather conditions were shown on the 8 a. m. weather map of December 27, and their progress south-eastward over the district with exceptionally severe weather, was forecast.

The cold wave, of unusual severity for December, moved southward, breaking records of long standing in some localities. It brought temperatures of about 0° F. or below in the Texas Panhandle and Oklahoma; 10° to 14° in northern Texas; and 20° to 26° in the southern portion; 0° to 8° in northern and 8° to 12° in southern Arkansas; 10° to 14° in northern and 12° to 19° in southern Louisiana. At New Orleans the minimum temperature was 19°, the lowest of record at this station.

The warnings and advices relative to protective measures which should be taken were generally followed and much loss to vegetation and live stock prevented. Although the harvesting of matured crops was pushed, the loss of vegetables in the fields, for which no protection was provided, exceeds \$1,000,000. Only about half of the people heeded the warning to drain their water pipes, and the pipes in more than 3,000 residences were burst by the freeze.

Storm warnings issued on December 7 were verified. No general storm occurred without warning.

Fire-weather warnings were issued on the 7th, 18th, and 24th and were justified.—*I. M. Cline, District Forecaster.*

*Denver, Colo., forecast district.*—December, 1917, was unusually dry and mild in this district, due to a succession of cyclonic areas which passed eastward along the northern storm tracks. At Modena on the 19th and at Phoenix and Modena on the 29th higher temperatures were reported than ever previously recorded at those stations so late in December. The district was notably free from storms. No cold waves occurred, except on the eastern slope, where there were rapid alternations of temperature, especially in eastern Colorado from the 7th to the 14th, and in the early part of the third decade when the weather was under the influence of anticyclones that moved southward from Alberta.

Cold-wave warnings were issued for portions of eastern Colorado on the 7th, 8th, 9th, 11th, 12th, 13th, 23d, and 24th, and for eastern New Mexico on the 7th, 9th, and 12th. The warnings were generally fully verified, except for eastern Colorado for the 24th and 25th. However, temperatures were 20° to 30° lower in eastern Colorado on the 24th and were close to 0° in portions of eastern Colorado on the 25th. Frost warnings were issued for south-central Arizona on several days during the fore part of the month, and frosts were frequent in that portion of the State, with a killing frost near Yuma on the 8th.—*Frederick W. Brist, Assistant Forecaster.*

*San Francisco, Cal., forecast district.*—Storms moved eastward from the North Pacific with great regularity during December, 1917; but with the exception of the storm of the 25th, which passed inland along the Canadian boundary, their passage was through northern British Columbia. The storm movement at so high a latitude at this season of the year gave almost continual rain or

snow in Washington and more than the usual number of days with precipitation in Oregon and Idaho, and very light precipitation in California and Nevada. In fact, drought conditions prevail in the two latter States.

Storm warnings were issued along the Washington and Oregon coasts on the 15th, 16th, 21st, 23d, 25th, 28th, and 31st, and along the California coast from Point Reyes northward on the 25th. In most cases they were verified, and it is believed that they were justified in every instance.

Areas of high pressure prevailed almost continually over the central and southern plateau region causing severe frosts almost daily during the first half of the month in California. While the temperature in the citrus belts fell below freezing on many nights, it did not reach a sufficiently low point to do any material damage.

Unusually high temperatures occurred in Idaho and Nevada on the 19th, and in portions of Washington, Oregon and Idaho on the 29th, when previous records for December were equalled or exceeded. The warm weather on the 29th caused a rapid melting of the snow in the mountains in western Washington, resulting in high rivers and some damage from floods.

This is probably the driest season in California since records have been kept, and there is less snow in the mountains than ever before known at this time of the year. Only isolated peaks are snow covered and the great area above 5,000 feet, at this season usually covered with several feet of snow, is now bare.—*G. H. Willson, District Forecaster.*

## 551.515 (213) (73) HURRICANES OF 1917.

By CHARLES A. DONNEL, Meteorologist.

[Dated: Weather Bureau, Washington, D. C., Feb. 3, 1918.]

Fewer storms than usual, of tropical origin, occurred during the year 1917. In fact only one disturbance that could be classed as a hurricane of the first magnitude viz, September 22-30, came within the field of our observations. However, it has seemed proper to include four storms in the present category, and their paths have been traced on Chart X (XLV—121) of this issue of the MONTHLY WEATHER REVIEW.

*Storm of August 9.*—Information concerning this storm is extremely meager. What at the time was believed to be a secondary center of a barometric depression moving eastward near the mouth of the St. Lawrence River appeared off the North Carolina coast. Later advices seem to disclose that this storm was of tropical origin, having formed east of the Virgin Islands and passing thence northwestward to the position charted on August 9.

*Storm of September 4.*—On September 4 a storm appeared south of the Bermuda Islands as shown by the weather report from Hamilton. The pressure was 29.46 inches with a wind of gale force and rain. The center of the disturbance passed to the eastward and northward of the islands some time between 12 o'clock noon and 4 p. m. the same date. No further facts in reference to this storm have been received.

*Storm of September 13-18.*—The second tropical storm of September made its first appearance as a definite disturbance on the morning of September 13 over eastern Cuba. During the following 24 hours the center moved northward to a position off the eastern coast of Florida. From that point the storm advanced northeastward and by the night of September 17-18 was off Cape Cod. It continued its northeastward movement and passed beyond Newfoundland on September 20.